VIRGINIA PORT AUTHORITY EMISSIONS

A Report by the
State Advisory Board on Air Pollution
Group 2
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I. Introduction

The 2005 State Advisory Board on Air Pollution, Group 2 (Diesel Group) was tasked to review the air emissions from Virginia Port Authority (VPA) facilities. The Virginia Department of Environmental Quality (DEQ) suggested this topic for several reasons: First, the captured data would improve the accuracy of the Hampton Roads Emission Inventory. In past years, the DEQ's inventory included assumed calculations for port emissions and they have been unable to quantify specific emissions. Second, the US Environmental Protection Agency (EPA) has requested emission data from states regulatory agencies with commercial ports. This request is in order to research the issues and provide guidance and potential funding to clean up emissions from ports. Finally, air emissions from marine terminals have recently attracted increased concern from both the EPA and the media, especially on the West coast.

The group developed the following mission statement for the project: Gather the necessary data and evaluate the strategies for controlling emissions from combustion of fuels at VPA facilities in Hampton Roads (Norfolk, Portsmouth, and Newport News). The inland port in Winchester, VA (operated by the VPA) and the port at Richmond (operated by City of Richmond) were excluded.

The study included an on site VPA facility visit for the team to become familiar with the operating aspects of the marine terminals, interviews with VPA representatives and their engineering consultants, and discussions with appropriate DEQ air quality planners. Emissions data was obtained from a detailed analysis of emissions and emission controls that apply to the equipment owned and operated by the VPA. The study excluded emissions from over the road trucks, trains, and marine vessel traffic that service the report. References are listed at the end of the report.

II. Executive Summary

Emissions from on site diesel engines at the VPA Hampton Roads facilities account for roughly one quarter of the total emissions from all Port activities. Emission levels have decreased significantly since 2001 when voluntary efforts were initiated to reduce fuel consumption and facility-wide emissions through a program of equipment replacement or retrofit, and improving operational efficiencies. These reductions were achieved despite double-digit annual growth in container movement. A continuation of these current emission reduction strategies is planned for the near term. Long-term growth projections indicate that ship traffic through the Ports of Virginia may double within 15 years. Strategies to control emissions during this period will largely depend upon the success of upcoming federal and international pollution control initiatives.

III. The Virginia Port Authority

The Virginia Port Authority (VPA) is an agency of the Commonwealth of Virginia which reports to the Secretary of Transportation. The VPA is the state's leading agency for international transportation and maritime commerce and they are charged with operating and marketing the marine terminal facilities through which shipping trade takes place. They receive their revenue from the port's operations. The VPA issues state bonds for port infrastructure improvements and to purchase cargo handling equipment. The revenue from the port is used to pay the debt incurred on these state bonds. Since the Commonwealth of Virginia is a "right to work" state, state agencies cannot supervise union labor. The majority of the workforce employed at the marine terminals belongs to the International Longshoremen Association. Therefore, a non-profit company was developed in 1982 called Virginia International Terminals Incorporated (VIT) to operate and maintain the equipment at the VPA marine terminals.

The VPA markets the port with the "Port of Virginia" slogan. This marquee is used to describe the VPA terminals and operations, and is used interchangeably with VPA throughout this report.

The Port of Virginia is strategically located in the mid-Atlantic and the transportation infrastructure offers the shipping industry access to two-thirds of the U.S. population. More than 75 international shipping lines deliver goods to the terminals, and their port of call is divided amongst three marine terminals: the Norfolk International Terminal (NIT), the Portsmouth Marine Terminal (PMT), and the Newport News Marine Terminal (NNMT). The Port of Virginia has a natural deepwater harbor on the U.S. East Coast and is located just 18 miles from the Atlantic Ocean. The shipping channels are dredged to fifty-feet and provide easy access and maneuvering room for even the largest container ships. The port offers six direct-service trains to 28 major cities each day. More than 50 motor-carrier companies offer full freight-handling and load-consolidation services in the Hampton Roads area.

Picture 1. Aerial photo highlighting the three VPA marine terminals.

NNMT is located in the upper left hand corner, NIT is located in the middle and PMT is located near the bottom right corner in the picture.

Picture 2. Aerial photo of NIT.

NIT is the largest of the three marine terminals with approximately 608 acres of land and is one of the largest intermodal facilities on the East Coast. This terminal mainly handles containerized cargo and some break-bulk cargo. The term break-bulk refers to freight that cannot be containerized. Break-bulk is usually a commodity such as rubber, wood, paper, steel and oversized pieces of machinery.

Picture 3. Aerial photo of PMT.

PMT is the second biggest marine terminal in Hampton Roads with approximately 250 acres of land. The VPA leases a small segment of this property to APM/Maersk Terminals. The leased land is delineated by the dashed white line. Like NIT, PMT also handles containerized cargo and break-bulk cargo. There is very little intermodal rail service at PMT.

Picture 4. Aerial photo of NNMT.

NNMT is the smallest of the three terminals and encompasses approximately 150 acres of land. Like the two previous marine terminals, NNMT also handles containers and break-bulk freight.

Each terminal has its own warehouse space. The warehouses are used to store commodities such as steel, rubber, custom lumber and cocoa beans. The majority of the cargo in each warehouse is serviced with propane or electric fork lifts.

IV. VPA Cargo Handling Equipment Emissions

Diesel engines at ports generate emissions from on site cargo handling equipment, truck and locomotive traffic in and out of port, and marine vessels. In 2004, the National Resource Defense Council (NRDC) produced a report on a study of the 10 largest U.S. ports. The report showed that only about a quarter of the emissions come from on site operations. As shown in Figure 1, the NRDC estimated that cargo handling equipment generates approximately 25% of the total nitrogen oxide ($NO_{x)}$) emissions. The balance of the NO_x emissions is more or less evenly split by marine vessels and over the road trucks, with a small contribution made up by personal vehicles and train traffic.

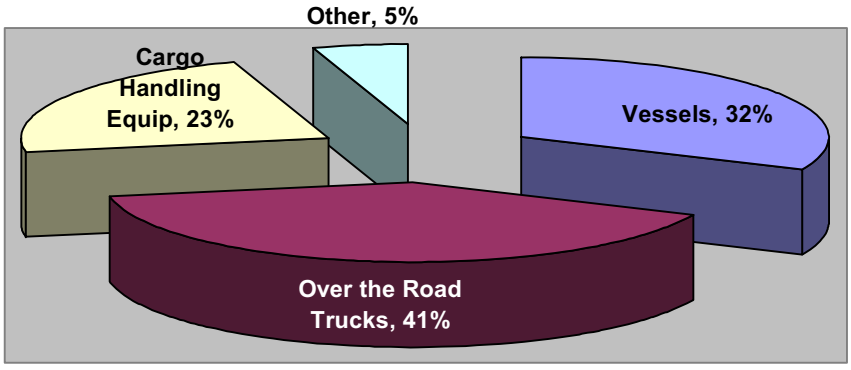

Figure 1 NRDC Typical NOx Emission from a Port

The NRDC also estimated the PM_{10} emissions from a typical port. As shown in Figure 2, the bulk of the PM_{10} emissions (74%) are from vessels and over-the-road trucks. They estimated that a typical ports cargo handling equipment generates only 24% of the total PM_{10} emissions.

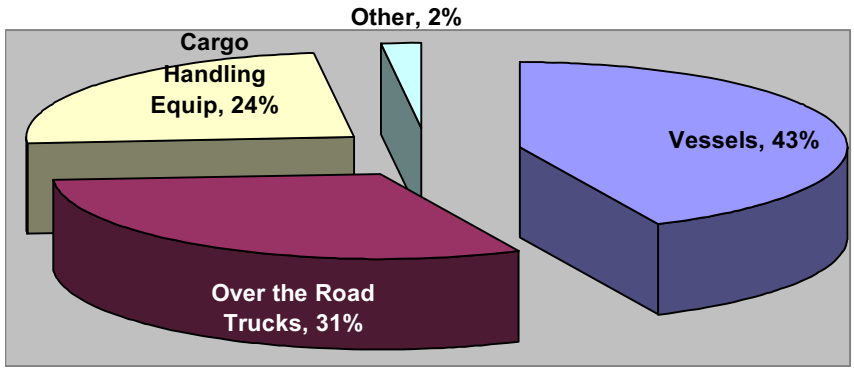

Figure 2 NRDC Typical PM_{10} Emissions from a Port

A comparison of the 2004 VPA VOC and NO_x emissions from their cargo handling equipment to total VOC and NOx emissions listed in the Hampton Roads Air Emission Inventory of 1999 shows that VPA emissions represent a very small fraction of the total.

Table ES-2: 2004 VPA Cargo Handling Equipment Total Emissions versus 1999 Hampton Roads Air Emission Inventory

	Hampton Roads (TPY)		*VPA (% of Hampton Roads)*	
Source	VOC	NO_x	VOC	NO_x
Point	4,500	26,700		
Mobile	39,900	19,700		
Area	21,100	32,100		
Total	64,600	78,500	0.4	1.7

In the spring of 2005, the VPA hired a consultant who completed a Mobile Source Emission Inventory. While producing the majority of emissions associated with VPA activities, marine vessels, Norfolk Southern locomotives, over the road tractor trailers, tenant-owned equipment, personally-owned vehicles, and dredging and contracted construction equipment were not included in the inventory

The VPA Mobile Source Emission Inventory divided the cargo handling equipment into four categories based on horsepower: Non-road equipment greater than 25 horsepower, non-road equipment less than 25 horsepower, on-road mobile vehicles and switch engines. The operational data that was assigned to each group included the annual operating hours, the load factor and the percent of idle time.

Currently, the VPA owns and operates 687 pieces of cargo handling equipment. The majority emissions are related to five types of equipment, which are the fork lifts, rubber tired gantry cranes, straddle carriers, hustlers and the container cranes. Since some of this equipment is not widely recognized outside of the port industry the following pictures are provided.

Picture 5. Rubber Tire Gantry Crane (RTGC) working over the rail.

Picture 6. Straddle Carrier placing a container on an over-the-road truck chassis.

Picture 7. Straddle Carrier working over a hustler

Picture 8. Container Crane working over a vessel.

The engine emissions were modeled in accordance with the standard EPA formulas for off-road and on-road emissions. The calculations take into account crankcase emissions operating under steady conditions. Diesel engines are known to emit ozone-forming NO_X and hydrocarbons. For this report, data on the following emissions were collected and evaluated: volatile organic carbons (VOCs), carbon monoxide (CO), NO_X, PM_{10} and sulfur dioxide (SO_2). Table 1 shows emissions in tons per year for the pollutants along with the percentage contribution for each of the major equipment groups previously discussed.

Table 1. 2004 Cargo Handling Equipment Emissions					
Equipment	*VOC (235 TPY)*	*CO (986 TPY)*	*NOx (1,334 TPY)*	*PM10 (91 TPY)*	*SO2 (185 TPY)*
Fork lifts	36%	42%	12%	10%	5%
RTGC	11%	15%	21%	32%	13%
Straddle Carrier	10%	9%	25%	19%	30%
Hustler	14%	8%	20%	19%	12%
Cranes	7%	6%	14%	12%	19%
Misc.	22%	20%	8%	8%	21%

The fork lift fleet accounts for 36% and 42% of the total VOCs and CO, respectively. This can be attributed to the design of the fork lift engines, which are designed to lift and place heavy objects. When they are used in this capacity, the engine burns fossil fuel at it peak operating temperature, resulting in less emission. However, when the fork lift is operated without a load, the engine will not reach its optimum burning rate and inefficient combustion will occur leading to more emissions.

Straddle Carriers account for 25% of the total NO_X and 19% of the PM_{10}. Currently, there are 95 straddle carriers operating at the terminals, however, there are only 22 RTGCs, and the 22 RTGCs account for 21% of the NO_x emissions and 32% of the PM_{10}.

The Port of Virginia currently has 22 container cranes in operation. Of those 22, thirteen are electrically powered and the remaining 9 are powered with diesel generators. The emissions listed for container cranes in Table 1 are for those 9 diesel-powered cranes.

SO_2 emissions can be directly correlated to the type of diesel fuel that is being supplied to the equipment. The Port of Virginia purchases off-road diesel which is known to have a higher amount of sulfur content, then on-road low sulfur diesel.

The VPA Mobile Source Emission Inventory provided data from 2001 through 2004. Table 2 is a summary of the total emissions, in tons per year. The change in emissions is listed in the right hand column.

Table 2: VPA Cargo Handling Equipment Emissions (Tons per year, TPY)			
Emission	*2001*	*2004*	*Difference*
VOC	244	235	-9
CO	998	986	-12
NO_x	1387	1334	-53
PM	97	91	-6
SO_2	185	165	-20

As Table 2 shows, there has been a significant decrease in the emissions of all five of pollutants for the last four years. These reductions occurred in spite of double-digit growth in container volume.

The port industry uses a standard called twenty-foot equivalent unit (TEUs). This standard is used to compare, and ultimately rank the ports based on container throughput. The term TEU relates to the size of a shipping container and these containers are manufactured in various lengths. The most common sized containers that are used for US trade are 20, 40, and 45-foot containers.

Every port keeps a yearly tally of each containers size that is shipped through their terminals. A factor is applied to each group to arrive at their total twenty foot containers shipped through the ports. The name TEU equates to the total amount of all containers that the port handled.

Table 3 lists the container throughput at the Port of Virginia from 2001 through 2004. The last column lists the net increase, as a percentage, when compared to the previous year.

Table 3: Ports of Virginia Container Throughput		
Year	*Million TEU*	*% increase*
2001	1.06	
2002	1.18	11
2003	1.35	14
2004	1.50	11

Table 4 shows the percentage change in emissions (Table 2) when they are normalized to the container throughput (Table 3). In the far right hand column lists the absolute change in emissions.

Table 4. Cargo Handling Equipment Emission Normalized To Container Throughput

Emission	*Δ%/1,000 TEU*	*Δ% Absolute*
VOC	-32%	-4%
CO	-30%	-2%
NO_x	-32%	-4%
PM_{10}	-33%	-6%
SO_2	-37%	-11%

Despite double-digit growth in container volume from 2001 through 2004, the VOC's, CO, NO_X, PM_{10} and SO_2 emissions have dropped 4%, 2%, 4%, 6%, and 11% respectively. When the emissions are compared to the level of business, they dropped 32%, 30%, 32%, 33%, and 37%. This represents a significant reduction in emissions from VPA onsite activities despite a growth in container throughput of nearly 30%. The VPA achieved these reductions voluntarily using the strategy discussed below.

It should be noted that recent DEQ monitoring data shows that the air quality for NO_x is well below the federal air quality standards. In 2004, the area measured an annual arithmetic mean of 0.016 ppm, where the federal standard for NO_x is 0.053 ppm. And, while during the 2001 to 2004 period the air quality in Hampton Roads was classified as "marginal attainment" for the 8-hour ozone criteria, in 2005 DEQ ozone monitors have registered a significant improvement in air quality within this region. Preliminary reviews of the 2005 summer data show the area to be attaining the 8-hour ozone standard with a three-year average of 78 parts per billion (ppb). The federal standard for ozone is 80 ppb.

V. The Port of Virginia Voluntary Emission Reduction Strategy.

The emission reductions seen at the Port of Virginia facilities from 2001 to 2004 are the result of a number of initiatives. In 1999, the VIT Engineering and Maintenance department (VIT E&M) implemented a change in their equipment acquisition procedures, requiring all newly purchased engines to meet or exceed the latest EPA emission requirements for on-road engines. They also reviewed their equipment inventory, identified equipment that could be replaced with cleaner burning engines, and initiated a phased replacement program.

There were several advantages to this effort. First, on-road engines are designed to have lower emissions. These engines are outfitted with a computer that controls the fuel system. Thus, the proper amount of fuel is appropriately allocated to the engine based on the demand placed on the engine. This type of fuel control would ultimately save fuel. At the time, diesel fuel prices were on the rise and the price of diesel fuel went from $0.67 gallon to nearly a $1.25 a gallon. A second advantage is that on-road engines are warranted for two-years while manufacturers offer a one-year warranty for off-road engines. Third, limits on idle time can be programmed into the computer. Currently, all computer controlled engines are programmed to shutdown after 15 minutes of idling.

VIT E&M also conducted a thorough review of their fork lift fleet, and reduced the total number of fork lifts from 239 to 185. They replaced 87 diesel and gas burning fork lifts with cleaner burning propane and downsized some pick-up truck engines from an 8 to 4-cylinders.

With regard to their hustler fleet, from 2001 through 2004 VIT purchased replacement hustlers with the latest EPA on-road certified engine. To date, the terminals have over 97 hustlers with low emitting on-road engines. New straddle carriers were also purchased with the latest EPA on-road engines.

There were no RTGC replacements during this timeframe; however, several of the RTGC engines were rebuilt. Despite the engine rebuilds the resulting emissions could not match that of the latest on-road engine emissions. This is why with 95 straddle carrier operating at the terminals account for 25% of the total NO_x and 19% of the PM_{10}, while the 22 RTGCs account for 21% of the NO_x emissions and 32% of the PM_{10}.

Other emission reduction efforts include evaluating fuel ionization equipment, purchasing hybrid vehicles, and converting passenger vehicles from gas to propane.

Recently, Global Positioning System (GPS) equipment was installed on the straddle carriers at PMT. The GPS data is fed into the Yard Management software to give accurate positions of both the container location and the straddle carrier.

This allows the software to assign container moves based on where equipment is located versus what straddle carrier is available. Using GPS will increase operational efficiency, translate into less operating hours, and lower emissions.

VI. Short Term Strategies to Reduce Emissions

The short term strategies for emission reductions at VPA facilities are similar to the VIT E&M on-going measures. Table 5 is a summary of those strategies for each type of equipment.

Table 5. Intermediate Strategies to Reduce Emissions

Equipment Type	*Strategy*
Forklifts	Retire/replace
RTGC's	Retrofit
Straddle Carriers	Retire, retrofit
Hustlers	Retire, retrofit
Cranes	Retire, retrofit

The southern portion of NIT is currently undergoing major infrastructure improvements. Construction will be on-going until 2012 and there are several phases to this project. It is projected, upon completion of this project, that the size of the RTGC fleet will be reduced from 22 to 10. The 10 RTGCs that remain will be likely candidates for engine retrofits. In addition diesel oxidation catalysts (DOCs) could be added to this equipment. A DOC is a catalyzed flow through a metallic or ceramic substrate. The catalytic reaction is used to convert pollutants to water and carbon dioxide. It has been demonstrated to reduce PM_{10} by 20-50% and hydrocarbons and CO by 90%.

The size of the hustler fleet will shrink as the RTGCs decrease. The hustlers are used to bring containers to and from the RTGCs. However, there will still be a need for hustlers at the terminal. As the hustler fleet ages, they will be replaced and equipped with the latest EPA certified on-road engine.

Additional NO_X reductions could be seen if the Port of Virginia converted its nine diesel powered cranes to electric power. The Dominion Power website states that power plants emit one-tenth the NO_X, but the same amount of SO_2, when compared to a stationary diesel powered generator.

VIT E&M has been researching the feasibility of introducing biodiesel, as an alternative source of fuel, to help reduce emissions. Biodiesel is a domestic distillate fuel that is derived by blending various vegetable oil, animal fats or used frying oils with diesel fuel. The two common blends found on the market today are B20 and B5. The term B20 means that it is a blend of 20 parts vegetable oil and 80 parts diesel fuel. For B5, the final blend would be 5 parts vegetable oil and 95 parts diesel fuel.

Of all of the fuel additives that are on the current market, biodiesel is very appealing to the Port of Virginia. Soy beans can be grown as a winter crop on Virginia farms and this would help prevent nitrogen run-off from entering nearby

rivers and the Chesapeake Bay. The EPA estimates that B20 provides about a 10-15% reduction in PM and 0-10% reduction for CO and hydrocarbons.

In order to provide cost data for using biodiesel, the two tables below describe the costs if B20 or B5 were used in 18 RTGCs at the port. Table 6 is the data and the EPA developed formula, Table 7 shows the results of formula and the expected drop or increase in specific emissions on the 18 RTGCs.

Table 6. Data for Cost per Ton of Emission Reductions for 18 RTGCs

Assumptions:		*Source*
Cost increase of biodiesel over diesel (B-20)	$ 0.20/gal	NDSU 2003 study
Cost increase of biodiesel over diesel (B-5)	$ 0.05/gal	NDSU 2003 study
Formula's for Emission Reductions %change={exp(a*[vol%biodiesel])-1}*100		
For NO_X, a = 0.0009794		Note 1
For PM, a = -0.0063840		Note 1
For HC, a = -0.0111950		Note 1
For CO, a = -0.0065610		Note 1
Gallons of 2004 diesel fuel that could be replaced with biodiesel	346,720 gallons	
Emissions from 2004 RTGC emissions that could be lowered with biodiesel		
NO_X	174.1 TPY	
VOC	15.5 TPY	
CO	81.1 TPY	
PM_{10}	21.8 TPY	

Note 1: 2002 USEPA draft study: "Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions."

Table 7. Results from Calculating Data in Table 6			
Blend of Biodiesel	*Emission*	*% Change in Emission*	Δ *TPY*
B-20	NO_X	+ 2.0 %	+ 3.44
	VOC	- 20.1 %	- 3.12
	CO	- 12.3 %	- 9.98
	PM_{10}	- 12.0 %	- 2.61
B-5	NO_X	+ 0.5 %	+ 0.85
	VOC	- 5.4 %	- 0.85
	CO	- 3.2 %	- 2.62
	PM_{10}	- 3.1 %	- 0.69

VII. Long Term Strategies to Reduce Emissions

Industry and government experts have indicated that container volume will continue to grow in the US seaports. The US Maritime Administration issued a report in 2004 that estimated the total volume of foreign trade moving through US ports is expected to double 1996 levels by the year 2020. This type of growth in waterborne cargo will mean more ship calls, more trucks, increased cargo-handling equipment and hours, resulting in more emissions. In 2004, it is estimated that 6,726 vessels called on the port. This figure is a combination of actual container vessels and barges and the estimated number of tugs required to dock and undock the ships. By 2020, the total number of vessels calls at the Port of Virginia could reach 10,000-12,000. The VPA is looking at utilizing computer models that are now being developed to project emissions from all Port activities (including those from trucks, vessels, and locomotives) based on future growth.

Long term strategies to reduce emissions will depend to a large extent on the success of a number of federal and international initiatives. A federal mandated requirement to produce diesel fuel with a lower sulfur content will begin in the summer of 2006. The goal of this initiative is to lower the sulfur content of on-road diesel from its current level of 500 parts per million (ppm, by weight) to 15 PPM. When that sulfur content is reached, this type of fuel will be called Ultra Low Sulfur Diesel (ULSD). Additionally, by 2010 all non-road diesel fuel will also be classified as ULSD.

The International Maritime Organization (IMO), which is a specialized agency under the United Nations, governs the prevention and control of the marine environment for ships. This governing body has assembled a treaty called the Maritime Pollution Annex VI. Within this Annex, emission limits have been set for SO_2 and NO_X from vessels built or modified after January 1, 2000. The IMO governing members approved this initiative in May 2005. The United States, Canada and Mexico abstained. These countries want additional limits set on PM, VOC and other green house gases as well as tougher limits on SO_2 and NO_X. . The IMO will reconvene in 2007 to hear the North American arguments.

Another initiative is the development of new federal emission standards for off-road diesel engines. This is schedule to take effect beginning in 2008 and will be fully implemented by 2014. The new standards will decrease exhaust emissions from off-road engines by more than 90% from their current levels (EPA420-F-04-032, May 2004). The EPA is also considering new regulations to decrease exhaust emissions from new marine and locomotive engines by as much as 90%. These regulations may come into effect as early as 2011 (EPA420-F-04-041, May 2004). As these new type of engines are incorporated into the day to day activities of the port and become more prevalent in equipment inventories, more reduction in emissions should be achieved. A point to note is that the current intent of the marine engine regulations is to regulate only engines for domestic commercial

vessels. For example, tugs, and ferries would be regulated, but ocean going vessels would fall under the IMO treaty previously mentioned.

Finally, the EPA has been working with port community nationwide to develop a strategy in reducing emissions from ports. . They also realize that port authorities are subject to mandates from Homeland Security measures and that programmed dollars for emission reduction might be rerouted to cover these mandates. The EPA will be issuing a list of solutions that will include programs such as grant money for engine retrofits, regulatory credits, low interest loans and rebates to aid owner-operator truck drivers in replacing their engines, to tax incentives. This report is due to be published in the spring of 2006.

References

1. National Resource Defense Council (NRDC), "Harboring Pollution, the Dirty Truth about US Port", 2004.

2. Malcolm Pirnie, "Virginia Port Authority 2004 Mobile Source Emissions Inventory", 2004.

3. EPA Regulatory Announcements, May 2004: Clean Air Non-road Diesel Rule; Clean Diesel Program for Locomotives and Marine Engines; Overview of EPA's Emissions Standards for Marine Engines.

Web Sites

www.epa.gov/ispd/ports/index.html
www.epa.gov/otaq/nonroad-diesel
www.epa.gov/otaq/marine.html
www.dom.com

SAB-AP Group 2 Members

Principle Contributors

Dan Demers	Virginia International Terminals, Inc
Doug Feuerbach	Dynax America Corporation
Joe Loschiavo	DuPont Company, Spruance Plant #2
Doris McLeod	Virginia Department of Environmental Quality
Sheryl Raulston	International Paper
Dudley Rochester	America Lung Association
Meghan Smith	Malcolm Pirnie
Tamara Thompson	Virginia Department of Environmental Quality
Heather Wood	Virginia Port Authority

Supporting Members

Tom Ballou	Virginia Department of Environmental Quality
Sanat Bhavsar	Yokohama Tire Corporation
Bob Blankenship	Environmental Quality Management, Inc.
Gerald Ramsey	Consolidation Coal Company
John Roland	Virginia Asphalt Association, Inc.